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▶ To cite this version:

Thomas Vallée, Eva Moreno-Galbis. Optimal time switching from tayloristic to holistic workplace organization. 2010. hal-00455149

HAL Id: hal-00455149

https://hal.science/hal-00455149

Preprint submitted on 9 Feb 2010

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Document de Travail
Working Paper

Lemna

EA 4272

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2010/07

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Optimal time switching from tayloristic to holistic workplace organization

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Abstract

The introduction of information and communication technologies over the past decades has fostered a process of internal workplace reorganization of firms who have tried to maximize their performance. Using a two stage optimal control technique, this paper provides analytical solutions to the conditions under which an economy decides to adopt a new organizational regime characterized by multitasking and an horizontal hierarchical structure (holistic organization). We consider two flexibility options: a) the possibility that only a part of the labor force is shifted to the modern workplace organization and, b) the possibility that the loss of productivity is not permanent. In all cases we conclude that the modern organization is adopted if and only if the productivity gains in the capital-goods sector compensate both the loss of expertise suffered by workers and the drop in consumption.

Keywords: Optimal switching control, Organizational regime, ICT.
JEL: C61, D92, L23, O33.

1 Introduction

Over the past decades the massive adoption of information and communication technologies (ICT), has been associated to a restructuring process in the internal workplace organization of firms as well as to a skill-upgrading process of the labor force. Most of the economic literature developed during the

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nineties focused on the relationship between ICT and the skill-upgrading of workers (see Berman et al. (1994) or Machin and Van Reenen (1998)). However since the late 90s there is an emerging theoretical and empirical literature interested in the introduction of high performance workplace organizational practices (HPWOP), such as job rotation, work teams, total quality control or quality circles, and in the progressive shift towards more flexible organizations.

The objective of this paper is to analyze the conditions under which an economy decides to switch from a traditional labor force organization (tayloristic organization) towards a more flexible organization (holistic organization). We study this issue within an optimal growth set-up where a benevolent planner, say a government, chooses the organizational structure over time so as to maximize social welfare (here we adopt the usual utilitarian view). From the normative point of view, this amounts to identifying an organizational structure that is socially optimal.

In their seminal theoretical contribution Lindbeck and Snower (2000) identify four interrelated forces that appear to be driven the workplace reorganization process of firms. First, the introduction of computerized information and communication systems has facilitated the decentralization of decision making and has enabled employees to become more involved in each other tasks through the introduction of job rotation and team work. Second, the introduction of flexible machine tools and programmable equipment has made capital stock more versatile and has required workers manipulating it to become more versatile too. Third, the steady growth of human capital per worker has taken the form of both, capital deepening (improvement in the performance of a particular skill) and capital widening (ability to acquire a variety of skills). This has permitted firms to reorganize and integrate tasks along the new organizational lines. Finally, the authors claim that workers' tastes have changed and now they prefer jobs including the exercise of diverse skills.

Our study introduces the interrelated forces (ICT and human capital widening) identified by Lindbeck and Snower (2000) as the main engine of switch towards a high performance workplace organization. More precisely, the economy has to decide whether to shift or not from a tayloristic organization characterized by a strict specialization by tasks (routine tasks), to an holistic organization characterized by job rotation, work teams, integration of tasks, learning across tasks and computerized production systems (non routine tasks). This decision involves two trade-offs:

(1) Between two sets of returns:
   (a) Returns from specialization or intratask learning: a worker's productivity at a particular task increases with her exposure to that task.
   (b) Returns from task complementarities or intertask learning: the worker uses the information and the skills acquired at one task to improve

her performance at other tasks.

In the tayloristic organization intratask learning is more important (returns from task complementarities are almost absent) while in the holistic organization intertask learning is stimulated and returns from specialization should fall since the worker is less time exposed to a particular task.

(2) Between the productivity gains promoted by the introduction of ICT and other flexible machine tools, and the costs (obsolescence and learning) induced by the technological change.

The adoption problem of a new workplace organization structure is similar to the one of technology adoption. The switch in both cases is costly since it requires some specific vintage physical and human capital and it involves learning (see Galor and Moav (2000), Parente (1994) or Greenwood and Jovanovic (2000)). At the same time, even if the new technology and organization structure should be more productive, the return to adoption and to innovation remains uncertain. Under which condition an economy should switch to a more modern technology and workplace organization knowing that this switching involves learning costs and, in the case of ICT (embodied technological process), obsolescence costs [2] ? What is the optimal time of switching?

Lindbeck and Snower (2000) [3] show how the advances in ICT, the widening of human capital and the change in the workers' preferences, seem to have progressively modified the shape of the firm's marginal revenue and cost, inducing multitasking adoption. Boucekkine and Crifo (2008) build a discrete time model in which the choice of the firm regarding its internal organization (tayloristic or holistic) is linked to the human capital level of the workers (above a certain threshold of human capital the firm adopts multitasking and below specialization). They also represent the dynamics of transition (induced by an exogenous shock) between a tayloristic equilibrium and a holistic equilibrium, but they do not explicitly model embodied technological progress (ICT).

To model the switch between organizational regimes we use the two-stage optimal control technique presented in Boucekkine et al. (2004). This approach uses standard optimal control theory but it is constructed as a dynamic programming method. It allows to obtain analytical results and gain economic insights on the economy's organizational and technological choices.

We solve a workplace organization adoption optimization program in continuous time. Technological progress is assumed to be embodied in new capital goods (we use the representation of Greenwood et al. (1997)) and it stimulates intertask learning (this retakes the idea of Lindbeck and Snower (2000)).

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[2] Boucekkine et al. (2003) and Krusell (1998) theoretically model the obsolescence costs induced by embodied technological progress.

[3] See also Lindbeck and Snower (1996).

The economy starts with a given organizational and technological menu characterized by the low presence of ICT (embodied technological progress) and the specialization of workers by tasks (intratask learning). We assume that, from the beginning, there is another menu available for the economy characterized by the more important presence of new technologies and multitasking (intertask learning). In deciding whether to switch from the first menu (tayloristic organization) to the second menu (holistic organization) the economy faces two trade-offs between: i) the productivity gains it obtains from having a more efficient capital good sector (thanks to the use of ICT) and the obsolescence costs[4] induced by this technological progress; ii) the increase in the returns from task complementarities fostered by ICT and the fall in the returns from specialization due to the reduction in the exposure time to each task. We will determine under which conditions the shift between the two menus takes place and what is the optimal timing for this adoption.

The paper is organized as follows. Next section presents some empirical evidence concerning the increased presence of multitask organizations. Section 3 describes the general theoretical framework used in the rest of the paper. Section 4 solves the organizational adoption problem with two flexibility options: a) the possibility that only a part of the labor force is shifted to the modern workplace organization and, b) the possibility that the loss of productivity is not permanent. In section 5 we analyze the impact of combining sharing the labor force and learning on the probability of postponing the switch to a new workplace organization. Section 6 concludes.

2 Some empirical evidence

Since the beginning of the 80s, occidental economies have evolved towards less specialized productive structures characterized by the increased presence of multitask (non routine) positions. As remarked by Lindbeck and Snower (2000) the introduction of computerized information and communication systems facilitated the decentralization of decision making, team work and job rotation. Moreover, these novel workplace organizational and technological practices required workers to be more versatile (widening of human capital). Nowadays, economists agree that the diffusion of novel technological practices is the main factor responsible for the observed organization changes.

Many papers have found empirical evidence on these evolutions. Concerning, the U.S economy, Osterman (1994) reports that already in the first half of the

[4] A higher level of embodied technical change is associated with a decrease in the relative price of capital, which raises the user cost of capital by the so called obsolescence costs (see Solow (1960)).

Employment shares and HPWOP diffusion in the United States					
	1980	1990	1996	1992 more than 50% of the core	1997 more than 50% of the core
High school dropouts (%)	19.1	12.7	9.4		
High school graduates (%)	38.0	36.2	33.4		
College graduates(%)	20.9	26.16	28.3		
College equivalents(%)	31.9	38.6	42.7		
Autonomous team				40.5	38.4
Job rotation				26.6	55.5
Total quality control procedures				24.5	57.2
Quality circles				27.4	57.7
None				36.0	15.0

The core represents around the half of the total number of employees in an establishment. The core job corresponds to the most important category of non managers workers directed involved in the production process of the product or the service of the establishment
Source concerning HPWOP: Osterman (1994), Osterman (2000). Source concerning the educational composition of employment: CPS 1980,1990, 1996.

Table 1
HPWO practices in United States.

90s a non negligible proportion of American firms had introduced some flexible forms of workplace organization, which suggests that the skill-upgrading process associated with technological adoption was simultaneously accompanied by a progressive change in workplace organization (see table 1). Bresnahan et al. (2002) confirm the strong correlation observed in the U.S. over the past decades between new technologies, HPWOP and qualified labor force (see table 2). More recently, Autor et al. (2003) conclude that ICT have progressively substituted workers employed in routine tasks while complementing those in non routine positions, whose productivity has been improved. The diffusion of novel technologies, has thus promoted the increase of multitask jobs (non routine) in the economy (see figure 1).

Measure	Computer Capital	Work Organization	Employee Skill	% College Educated	% Professionals
Computer Capital	1				
Work Organization	(+)***	1			
Employee Skill	(+)*	(+)***	1		
% College Educated	(+)	(+)***	(+)***	1	
% Professionals	(+)***	(+)***	(+)	(+)***	1

Table 2
Correlations between measures of ICT, HPWOP and human capital.
Spearman rank order correlations controlling for industry(9 sector dummy variables), employment and production worker composition. Observations: 251-401, due to non response and some measures limited to some of the wave surveys. (*) p< .1, (**) p< .05, (***) p< .001. Test is against the null hypothesis that the correlation is zero.

With regards to European economies, Spitz-Oener (2006) confirms Autor et al.

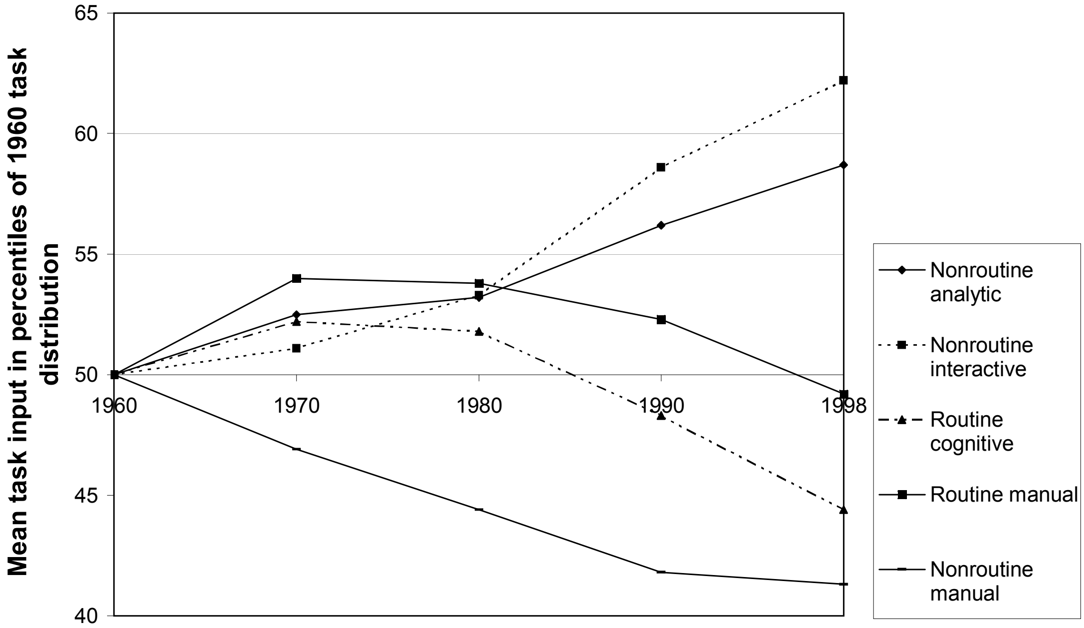

Fig. 1. Trend in routine and non routine task input, 1960 to 1998.

Source: Autor et al. (2003).

(2003)'s findings for Germany. Joergensen (1998) concludes that in Denmark the introduction of ICT fostered a movement towards integrative organizational configurations. Working with British and French data Caroli and Van Reenen (2001) find that the recent adoption of HPWOP has increased the relative demand for skilled labor and has improved productivity growth in skill intensive firms. The adoption and diffusion of novel technologies has therefore been associated with a generalized shift of economies towards more flexible workplace organizations based on job rotation, team work, quality control procedures and an horizontal hierarchical structure.

Black and Lynch (2004), Bresnahan et al. (2002) or Askenazy and Gianella (2000), among others, have deepen the analysis regarding the effects of novel technological and organizational practices by considering productivity issues. They find that firms' economic performance is only improved when technological adoption is associated with a simultaneous workplace reorganization. ICT adoption by its own does not seem to have any significant impact in performance.

In sum, most technological progress developed over the past decades is embodied in new capital goods. This implies that by simply investing in physical capital, economies support a technological shock, since this capital embodies by default new technologies. Given this shock, it may be in the interest of the economy to shift towards more flexible organizational structures, allowing to fully profit from new technologies. The decision to change the workplace organization is likely to depend on the relationship between the expected gains and costs of reorganization. Under which conditions are we likely to observe the increasing trend of multitask organizations estimated by Autor et al. (2003) for the U.S. economy or by Spitz-Oener (2006) for Germany? Our paper develops a theoretical model which, from a macro perspective, deals with this switching decisions between technological and organizational regimes.

3 The model

3.1 The baseline model

We consider two sectors. A final-goods sector producing consumption goods and a capital-goods sector transforming each unit of invested final good into capital. The production technology in the final-goods sector is given by an AK function of the following form:

$$Y = AK[N \cdot H] \tag{1}$$

where Y corresponds to output, A stands for total factor productivity (disembodied or neutral technical progress), K for capital stock, N is the number of workers and H should be interpreted as "efficiency units" of work or the "quality of labor". Indeed the term H is decomposed as follows:

$$H = R_s + q \cdot R_c \tag{2}$$

where R_s is a positive constant representing the returns from specialization or intratask learning (productivity of the worker resulting from the exposure to a task), q stands for embodied technological progress (associated with new information and communication technologies) and R_c is a positive constant representing the returns from task complementarities.

The final good may be used either for consumption, C, or as an input, I, in the production of capital goods: $Y = C + I$. The production function of the capital sector is inspired from Greenwood et al. (1997):

$$\dot{K} = q\, I = q\, (Y - C) \tag{3}$$

where the term q (embodied technological progress) reflects the productivity of the capital-goods sector. We assume the absence of capital depreciation.

The economy is inhabited by a decision maker who maximizes its intertemporal utility function in an infinite horizon:

$$\int_0^{\infty} u[C(t)]\, e^{-\rho\, t} dt \tag{4}$$

and whose resource constraint is given by $Y = C + I$, and where the initial capital stock is given, $K_0 > 0$.

The organizational and technological menu are represented by two positive numbers $(R_{s_i},\, q_i)$ where i corresponds either to the tayloristic menu or to the holistic one. We assume an economy that initially starts with a traditional menu characterized by $(R_{s_{tr}},\, q_{tr})$. However from $t = 0$ there is a more modern organizational and technological menu available $(R_{s_h},\, q_h)$. Returns from task specialization associated to the tayloristic menu are more important than those associated to the holistic menu $(R_{s_{tr}} > R_{s_h})$. In contrast embodied technological progress is more important in the modern menu, $q_{tr} < q_h$. Moreover, because new technologies stimulate returns to task complementarities we find that: $q_{tr} \cdot R_c < q_h \cdot R_c$. In sum, the economy can switch to a modern menu where the capital-goods sector will be more efficient but where the "quality of labor", H, may be greater or smaller than in the initial menu, depending on the size of intratask and intertask learning $(R_{s_{tr}} + q_{tr} \cdot R_c \lesseqqgtr R_{s_h} + q_h \cdot R_c)$.

Since the returns from task specialization and the embodied technological progress remain fixed for each of the regimes, any initial domination of one particular regime will remain valid forever. As a consequence, the optimal switching time is only today $(t_1 = 0)$ or never $(t_1 \to \infty)$.

3.2 Sharing the labor force and introducing a learning process

Instead of analyzing under which conditions the economy decides to completely shift from a traditional tayloristic menu to a more modern holistic menu, we prefer to consider a more general framework where only a share of the labor force is shifted to the modern organization. This assumption corresponds well to the empirical evidence presented in section 2. Table 1 reveals that only a proportion of firms in the economy actually adopts flexible workplace practices. We interpret this finding as if only a share of the labor force in the economy had been shifted to the holistic organization.

We define α as the proportion of workers employed in the tayloristic regime : $\alpha = \frac{N_{tr}}{N}$. If $\alpha = 1$ no one in the labor force is shifted to the new organization regime, so that, there is no loss of expertise or gain in the capital-goods sector efficiency. When $\alpha = 0$ all the labor force is shifted. And, finally, when $0 < \alpha < 1$ the loss in the specialization returns derived from the switch is partially corrected by the proportion of workers remaining in the tayloristic regime.

Similarly, the efficiency gains in the capital sector are mitigated.

On the other hand, our baseline specification assumes that returns from task specialization associated with the tayloristic menu are more important than those associated to the holistic menu ($R_{s_{tr}} > R_{s_h}$). If the possibility of learning is introduced, returns from task specialization are defined as $R_s(t) = R_{tr}$ if $0 \leq t < t_1$, where t_1 stands for the optimal switching date, and by:

$$\begin{aligned} R_s\,(t) &= R_h + \alpha\Delta_R + (1-\alpha)R_s^{\star}(1-e^{-t_1}) \\ &= R_h + \alpha\Delta_R + (1-\alpha)R_s^{\star} - (1-\alpha)R_s^{\star}e^{-t_1} = \tilde{R}_s - (1-\alpha)R_s^{\star}e^{-t_1} \end{aligned} \quad (5)$$

for $t_1 < t$, where $R_s^{\star} \in [0, \Delta_R]$. $R_s^{\star}$ indicates the maximum amount to be learnt at the date of switch, and

$$\begin{aligned} \Delta_R &= R_{tr} - R_h > 0 \\ \Delta_q &= q_{tr} - q_h < 0 \end{aligned}$$

Equation (5) means that the loss in expertise following an organizational switch from a tayloristic to an holistic regime is not longer permanent when learning is introduced. Workers who switch are supposed to recover their full productivity period by period, and to asymptotically eliminate the organizational gap. If all the labor force is switched at $t = 0$, then $\alpha = 0$ and there is a loss of expertise measured by Δ_R. The latter the switch, the less important is the loss of expertise. More precisely, if the switching date tends towards infinity, then R_s tends to 1 (no loss of expertise). Our modeling introduces a possible incentive to wait. Following Greenwood and Jovanovic (2000), established skills are often destroyed, and productivity can temporarily fall upon a switch to a new technology. Similarly, a new organizational structure may first be operated inefficiently because because of a loss of experience. That is, when a switch to another kind of organization occurs, some specific knowledge is at least partially lost, and another round of experience accumulation (or learning) is needed.

As will be detailed latter on in the paper, the most relevant cases we can find when combining sharing of the labor force and learning are the following ones:

- If $\alpha = 0$ and $R_s^{\star} = 0$ (no share and no learning) then $R_s = R_h$. The solution will be still either to switch today or never.
- If $0 < \alpha < 1$ and $R_s^{\star} = 0$ (share of labor force and no learning) then $R_s = R_h + \alpha\Delta_R$. As we will see, in such a case the solution is always today or never, but sharing the labor force will reduce the number cases where no switching is adopted in comparison with a total switch case.
- If $\alpha = 0$ and $0 < R_s^{\star} \leq \Delta_R$ (no share and learning) then $R_s = R_h + R_s^{\star}(1 - e^{-t_1})$. This converges to R_{s_h} if $t_1 = 0$ and $R_{s_h} + R_s^{\star} \geq R_{tr}$ if $t_1 \to \infty$. Waiting may become an option, since it decreases the initial cost of a shift.

- $0 < \alpha < 1$ and $0 < R_s^\star \leq \Delta_R$, corresponds to the general formulation of (5). In such a case sharing the labor force may decrease the probability of immediate switch and increase the probability of postponing the switch.

4 Resolution of the model

Denoting t_1 the switching time, our optimal control problem can be represented as follows:

$$\max_{C,t_1} U(C,t_1) = \int_0^\infty u[C(t)]\, e^{-\rho\, t} dt = \int_0^{t_1} u[C(t)] e^{-\rho t} dt + \int_{t_1}^\infty u[C(t)] e^{-\rho t} dt,$$

with K_0 given, and subject to:

$$Y_{tr} = AKN[R_{s_{tr}} + q_{tr} \cdot R_c] \text{ and } \dot{K} = q_{tr}\, I = q_{tr}\, (Y_{tr} - C) \tag{6}$$

if $0 \leq t < t_1$, and

$$Y_h = AKN[R_s(t) + \overline{q} R_c] \text{ and } \dot{K} = \overline{q}\, I = \overline{q}\, (Y_h - C) \tag{7}$$

if $t_1 \leq t < \infty$.

with $R_s(t)$ defined by (5) and where

$$\overline{q} = \frac{N_{tr}}{N} q_{tr} + \frac{N_h}{N} q_h = q_h + \alpha \Delta_q.$$

That is, one must choose the consumption path and the time of switch that maximize its lifetime welfare. Because welfare performances of the two organizational regimes are additively separable we use a two stage optimal control technique consisting simply in solving a sequence of Pontryagin problems to deal with the model (Tomiyama (1985) and Tomiyama and Rossana (1989)).

The sequence of Pontryagin problems can be summarized as follows :

(1) Assuming that the economy effectively switches at date t_1, we first need to deal with the optimal control problem associated to the holistic regime:

$$\max_C \; U_h(C,t_1) = \int_{t_1}^\infty \ln(C(t)) e^{-\rho t} dt \tag{8}$$

subject to (7), where $K_1 = K(t_1)$ is given. The solution to this Pontryagin problem provides the optimal welfare performance of the holistic regime ($U_h^*(K_1,t_1)$) and the optimal Hamiltonian value for t_1 and K_1

given ($H_h^*(K_1, t_1)$). Both are then used to solve the second Pontryagin sequential problem.

(2) Taking into account the results of the first optimizing problem, the decision maker must choose the consumption path and the switching time that maximize its expected lifetime welfare. More formally its problem can be formulated as follows:

$$\max_{\{C,\, t_1\}} U_{tr}(C,t) = \int_0^{t_1} \ln(C(t))e^{-\rho t}dt + U_h^*(K_1, t_1) \tag{9}$$

subject to (6), where K_0 is given, $K_1 = K(t_1)$ is free. Assuming that t_1^* is an interior point, we are left with an auxiliary problem for the tayloristic organization with free end point and free terminal time. Using maximum principles gives us the optimal Hamiltonian value, $H_{tr}^*(K_1, t_1)$.

(3) Adding the constraint that the continuity of the co-state variable at t_1 must hold (Tomiyama (1985)), an interior switching time exists if $H_h^*(t_1, K_1) = H_{tr}^*(t_1, K_1)$.

From these resolution steps, an optimal interior point, $0 < t_1 < \infty$, exists if the following condition holds:

$$0 < \underbrace{\underbrace{\left(\overline{q}\overline{A}_h - q_{tr}\hat{A}_{tr}\right)}_{\text{organizational productivity gain}}}_{\equiv G} - \underbrace{\underbrace{\rho \ln(\frac{\overline{q}}{q_{tr}})}_{\text{immediate drop of consumption (loss)}}}_{\equiv Z} < \underbrace{\underbrace{(1-\alpha)\overline{q}ANR_s^\star}_{\text{organizational productivity loss}}}_{\equiv V} \tag{10}$$

with $\overline{A}_h = AN(\tilde{R}_s + \overline{q}R_c)$ and $\hat{A}_{tr} = AN(R_{s_{tr}} + q_{tr}R_c)$, where $\overline{q} = q_h + \alpha\Delta_q$. Because $\overline{q} > q_{tr}$ it is simple to verify that $\overline{A}_h > \hat{A}_{tr}$. Furthermore one can easily check that $G'_\alpha = \frac{\partial G}{\partial \alpha} < 0$, $Z'_\alpha = \frac{\partial Z}{\partial \alpha} < 0$ and $V'_\alpha = \frac{\partial V}{\partial \alpha} < 0$, that is, sharing the labor force reduces the total losses $(Z+V)$ but also the gain from switching (G).

From the second stage of the sequential problem we derive proposition 1, presented and economically interpreted in the following section.

4.1 General proposition and interpretation

Proposition 1 *Assume $\Delta q < 0$ and $\Delta R > 0$ then*

- *i) if $G - Z \leq 0$ then $t_1 \to \infty$. The total net advantage of switching is not positive, even without the loss of expertise. Thereby, adoption is never* *optimal and the economy remains in the tayloristic organization.*

- *ii) if $G - Z \geq V$ then $t_1 \rightarrow 0$. Since the total net advantage is enough to compensate the immediate loss of consumption and expertise, there is no reason to wait for the switch (the optimal time of switching is $t = 0$).*
- *iii) if $0 < G - Z < V$, then switching is advantageous since the new organizational form allows some net gain but these gains are not enough to immediately compensate the loss of expertise. The firm must delay the time of adoption in order to compensate the impact of this expertise loss, with $t_1^* = -\ln\left[\frac{\rho}{(1-\alpha)\overline{q}ANR_s^*}\left(\ln(\frac{q_{tr}}{\overline{q}}) + \left(\frac{\overline{q}\overline{A}_h - q_{tr}\hat{A}_{tr}}{\rho}\right)\right)\right]$.*

Economic interpretation

The intuition behind the results displayed in proposition 1 is quite simple. In our framework the production function of the capital-goods sector is defined as:

$$\dot{K} = q\ I\ , \tag{11}$$

where the term q stands for the productivity of the sector. More precisely it indicates the number of units of capital that can be obtained from each unit of invested final good. Because q represents the number of units of capital per unit of final good, $1/q$ will correspond to the number of final goods required to obtain one unit of capital. That is, $1/q$ is the relative (shadow) price of capital.

Our theoretical framework retakes the idea presented in Milgrom et al. (1991) or Lindbeck and Snower (2000) among others, who consider that the switch from a traditional organization to an holistic one is promoted by the introduction of new technologies (embodied technological progress). In words the change in the organizational regime is fostered by an increase in q, and thus by a fall in the relative shadow price of capital ($1/\overline{q} < 1/q_{tr}$). This induces a reassignment of the resources existing in the economy in favor of the capital-goods sector and against the consumption-goods sector (relatively less final goods are devoted to consumption and more to investment). Consumption levels are thus higher under the tayloristic regime than under the holistic regime. The welfare cost of this drop is referred as the obsolescence cost inherent to embodied technological progress. Because the utility function is logarithmic, the obsolescence costs are represented by $\rho ln(\overline{q}/q_{tr})$, where ρ is the impatience rate. The bigger $\overline{q}$ with respect to q_{tr} the more important is the welfare (consumption) drop.

On the other hand, when the economy switches to the holistic regime, the improvement in the efficiency of the capital-goods sector ($\overline{q}\overline{A}_h - q_{tr}\hat{A}_{tr}$) may be large enough to compensate the loss of expertise ($(1-\alpha)\overline{q}ANR_s^\star$) derived from the switch.

5 Particular case: combining sharing of the labor force and learning

5.1 Impact of sharing the labor force in the no learning case

Proposition 2 *If $q_h R_{s_{tr}} - q_{tr} R_{s_h} > 0$ and $q_h R_c - q_{tr} R_c + R_{s_h} - R_{s_{tr}} < 0$, sharing the labor force increases the number of cases where switching is adopted.*

Proof of the proposition 2

Since $R_s^\star = 0$, then $V = 0$, and the economy shifts to the new organizational regime if $G(\alpha) - Z(\alpha) > 0$. Assume that there exists $\alpha^* \neq 0, 1$ such that the gain from switching is maximized. Then, α^* must verify:

(1) $G'_\alpha - Z'_\alpha = 0 \Rightarrow \alpha^*$ with

$$\alpha^* = \frac{\sqrt{AN}(4q_h^2 R_c - q_{tr}R_{s_h} + q_h(-4q_{tr}R_c + 4R_{s_h} - 3R_{s_{tr}}))}{4\sqrt{AN}(q_h - q_{tr})(q_h R_c - q_{tr}R_c + R_{s_h} - R_{s_{tr}})} \pm \frac{\sqrt{8(q_h - q_{tr})\rho(q_h R_c - q_{tr}R_c + R_{s_h} - R_{s_{tr}}) + AN(q_{tr}R_{s_h} - q_h R_{s_{tr}})^2}}{4\sqrt{AN}(q_h - q_{tr})(q_h R_c - q_{tr}R_c + R_{s_h} - R_{s_{tr}})}$$

(2) $G''_\alpha - Z''_\alpha \equiv (q_h - q_{tr})\left(\frac{\rho(q_h - q_{tr})}{\overline{q}^2} + 2AN(q_h R_c - q_{tr}R_c + R_{s_h} - R_{s_{tr}})\right) < 0.$

From either condition (1) or (2) one can derive the necessary conditions that $q_h R_c - q_{tr}R_c + R_{s_h} - R_{s_{tr}} < 0$ and $q_h R_{s_{tr}} - q_{tr}R_{s_h} > 0$. Then one must check either or not the parameter values that are compatible with condition (2) and, with $\alpha^* \in]0, 1[$. Remark that sharing the labor force reduces both the productivity gain and the drop of consumption. Only when the reduction in the productivity is smaller than the reduction in consumption, the switching condition becomes less restrictive under sharing. As shown in figures (A.1-A.4), this is generally the case when ρ is low.

We now combine the sharing of the labor force between the tayloristic and the holistic menu with the possibility of learning, so that the initial productivity loss in case of switch progressively disappears.

Proposition 3 *If the organizational productivity gain is high enough sharing the labor force decreases the probability of immediate switching and increases the probability of postponing the switch.*

Proof of proposition 3

When considering the switching decision, the date of switch (immediate or delayed) depends on the value of V. With $V > 0$, the firm switches immediately if $G-Z > 0$, and waits if $-V < G-Z-V < 0$. Sharing increases (decreases) the probability of switching immediately if $(G^{'}_{\alpha}-Z^{'}_{\alpha}-V^{'}_{\alpha}) > 0$ $((G^{'}_{\alpha}-Z^{'}_{\alpha}-V^{'}_{\alpha}) < 0)$ whereas it increases the probability of waiting if $V^{'}_{\alpha} < G^{'}_{\alpha} - Z^{'}_{\alpha}$. Since we have $V^{'}_{\alpha} < 0$ (sharing the labor force reduces the expertise loss) the overall impact on $G - Z - V$ is undeterminate since it depends also on the sign of $(G^{'}_{\alpha} - Z_{\alpha})$. Assume first that we have $(G^{'}_{\alpha} - Z^{'}_{\alpha}) > 0$. Then automatically, we get $(G^{'}_{\alpha} - Z^{'}_{\alpha} - V^{'}_{\alpha}) > 0$. Sharing the labor force will promote an immediate switch when $(q_h - q_{tr})$ is small $(G^{'}_{\alpha} - Z^{'}_{\alpha} > 0)$. In this case, there is no much to gain in terms of productivity when switching to the holistic menu, therefore sharing the labor force limits the loss of expertise and drop in consumption without implying a big deterioration in productivity. Conversely, if $(q_h - q_{tr})$ is high enough, the impact of sharing the labor force will be negative on the overall gain. As a consequence, the probability of waiting will increase when α is high. That is, we may have $(G - Z - V) > 0$ for small values of α and $(G - Z - V) < 0$, where $G - Z$ is still positive, for high values of α. Waiting becomes more likely than switching immediately when the number of workers shifted to the holistic menu falls. Furthermore, as α increases, the waiting time increases. Appendix A.2 provides numerical examples on the various switching possibilities presented above.

6 Conclusion

This paper seeks to gain insights on the conditions that allow a switch from an organizational regime characterized by a strong specialization by task and a vertical hierarchy (tayloristic organization) to a regime characterized by a more horizontal structure where workers implement several tasks (holistic organization). Recent literature (see Lindbeck and Snower (2000), Bresnahan et al. (2002), Autor et al. (2003) or Spitz-Oener (2006)) has found that the introduction of ICT has been associated to a process of internal workplace reorganization of firms, who have tried to endow themselves with a more flexible structure. However, to our knowledge, there is no much theoretical literature concerning the conditions that yield the organizational adoption decision. We study this issue within an optimal growth set-up using the two-stage optimal control technique presented in Boucekkine et al. (2004) to analytically determine these adoption conditions.

Even if the introduction of computerized information and communication systems as well as flexible machine tools and programmable equipment has facilitated the decentralization of decision making, has enabled employees to become more involved in each other tasks and has required workers to become more versatile, a organizational change is not free of cost. On the one hand workers are likely to suffer a loss in expertise and firms will have to bear a learning cost. On the other hand, the improved productivity in the capital-goods sector (coming from ICT adoption) is likely to foster a resource reallocation going against the consumption-goods sector and leading to a fall in consumption levels. The decision-maker faces therefore a trade-off between the productivity gains promoted by the organizational change and the losses it also induces.

This paper considers two flexibility options: a) the possibility that only a part of the labor force is shifted to the modern workplace organization and, b) the possibility that the loss of productivity is not permanent. We find that if productivity gains in the capital-goods sector compensate the loss of expertise suffered by workers in the consumption-goods sector as well as the drop in consumption there will be a switch towards the holistic organization. Moreover, we prove that, in the absence of learning, the probability of switching is higher if the economy shifts to the new organizational regime only a fraction of its labor force. Furthermore, we compute the optimal value of this share. Conversely, in the presence of a learning process, sharing the labor force between the two organizational regimes increases or decreases the probability of switching depending on the expected productivity gains from the holistic organization.

A Numerical applications

A.1 Sharing the labor force and no learning

Le set $q_{tr} = 1$, $R_{s_{tr}} = 1$ and $R_c = 1$. From figures A.1-A.4, one can check the impact of both sharing the labor force and changing the discount rate. If the discount rate is very reduced, then the economy must switch immediately since the drop in consumption is low. An increase of the discount rate allows an optimal value of $\alpha^* \neq 0$ to exist. If the discount rate is too high, then the cost of switching is always greater than the productivity gain, and one must never switch.

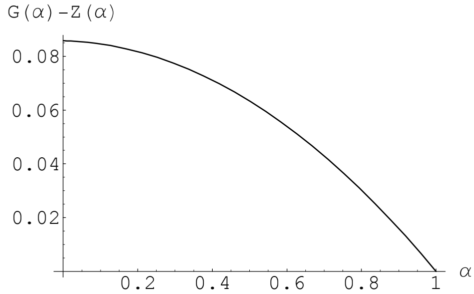

Fig. A.1. $R_{s_h} = 0.5$, $q_h = 0.5$, and $\rho = 0.01$.

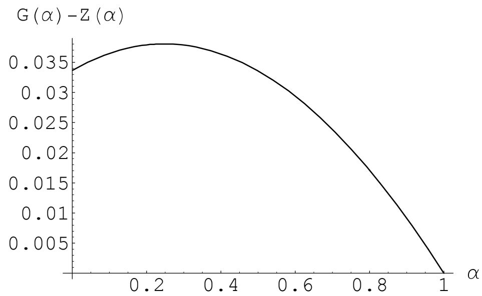

Fig. A.2. $R_{s_h} = 0.5$, $q_h = 0.5$, $\rho = 0.1$, and $\alpha^* = 0.247$

A.2 Sharing the labor force and learning

With $A = N = R_c = 1$, $\rho = 0.5$, $R_s^{\star} = 0.2$ and with $q_{tr} = 0.28$ we have in the total switching case ($\alpha = 0$) the following results:

- if $q_h = 0.3$, then $G(0) - Z(0) < 0$: No switching
- if $q_h = 0.4$, then $G(0) - Z(0) > 0$ but $G(0) - Z(0) - V(0) < 0$: Waiting

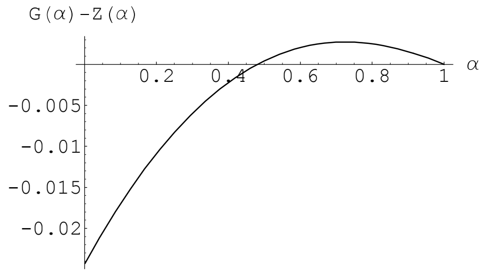

Fig. A.3. $R_{s_h} = 0.5$, $q_h = 0.5$, $\rho = 0.2$ and $\alpha^* = 0.725$.

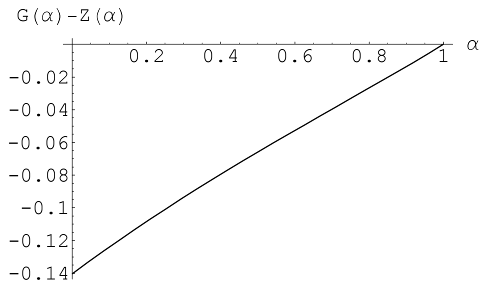

Fig. A.4. $R_{s_h} = 0.5$, $q_h = 0.5$, and $\rho = 0.4$.

- if $q_h = 0.6$, then $G(0) - Z(0) - V(0) > 0$: Switch immediately

With partial switching, the results change as follows:

- if $q_h = 0.3$, then $G(\alpha) - Z(\alpha) < 0$, $\forall\alpha$: always no switching
- if $q_h = 0.4$, then $0 < G(\alpha) - Z(\alpha) - V(\alpha) < 0$, $\forall\alpha$: always waiting
- if $q_h = 0.6$, then (see figure A.5)
  · if $\alpha < 0.31911$ then $G(\alpha) - Z(\alpha) - V(\alpha) > 0$: Switch immediately
  · if $\alpha \geq 0.31911$ then $G(\alpha) - Z(\alpha) - V(\alpha) \leq 0$: Postpone switching

From figure A.5, one can check that for small value of α, the impact of sharing the labor force will be to reduce the net gain. Hence waiting before switching will be more likely to happen as an optimal solution.

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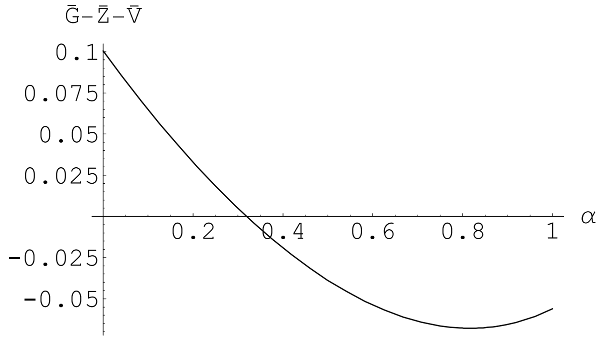

Fig. A.5. Values of $\overline{G} - \overline{Z} - \overline{V}$.

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